A Vision for Crop Improvement and Food Security in a Changing Climate

Speakers: Alison Bentley, Charlie Messina, Geoff Morris, Tony Gathungu, and Mark Edge
Introductory Remarks: Nora Lapitan
Moderator: Angela Records
Introductory Remarks

Nora Lapitan
Research Community of Practice Lead,
USAID Bureau for Resilience and Food Security
Today’s Speakers

Alison Bentley
Director, CIMMYT’s Global Wheat Program

Charlie Messina
Professor of Predictive Breeding in the Department of Horticultural Sciences, University of Florida

Geoff Morris
Associate Professor of Crop Quantitative Genomics, Colorado State University

Tony Gathungu
Global Head of Seeds2B, The Syngenta Foundation for Sustainable Agriculture (SFSA)

Mark Edge
Director of Partnerships, Seeds & Traits Business Development for LMICs, Bayer
A Vision for Crop Improvement and Food Security in a Changing Climate

Nora Lapitan
Bureau for Resilience and Food Security
2022-2026 Global Food Security Research Strategy (to be launched in Spring 2022)

- Annotated outline for input until Feb. 11, 2021
- Three priorities to address the goal of reducing poverty and child stunting by 20%:
  - Climate change
  - Diet quality and affordability
  - Diversity, equity, and inclusion
Climate change is forecasted to increase global poverty rates

- 9.4% global extreme poverty rate (people earning $1.90 or less/day)
- Greatest concentration of poverty in SSA and South Asia
- Climate change will drive up to $132 million people to extreme poverty by 2030

Source: PovcalNet
Prevalence of child stunting is positively correlated with extreme poverty

- Over 20% (149 M) of children are stunted
- Decreased incomes and higher food prices due to climate change will lead to higher rates of child stunting, especially in rural areas (Lloyd et al. 2018. doi: 10.1289/EHP2916)

Source: WHO/World Bank/UNICEF 2018
Agricultural productivity growth has made food cheaper and saved land

In low income countries, lower food prices is a major driver of poverty reduction and economic development

Research is the Primary Driver of Agriculture Productivity Growth

TFP = Total factor productivity (combined productivity of all inputs)

Increase in TFP comes from cost-reducing innovations

Sources: Authors’ calculation based on value of production data from FAOSTAT (2020) and TFP estimates from USDA, ERS (2019).
Environmental threats to crop productivity

- Temperature Variability
- Shifting precipitation patterns
  - Drought
  - Flooding
  - Salinity
- Emergence of crop pests and pathogens
- Elevated surface CO2 concentrations
Impact of increasing temperature on crop yields

Each degree-Celsius increase in global mean temperature would, on average, **reduce global yields** of:

- Maize by 7.4%
- Wheat by 6.0%
- Rice by 3.2%
- Soybean by 3.1%.

Source: Zhao (2017) https://doi.org/10.1073/pnas.1701762114
Today’s Speakers

Alison Bentley
Applied Solutions to Safeguard Future Wheat

Charlie Messina
Breeding for Climate Change: Perspectives

Geoff Morris
How to adapt sorghum for climate change? NARS-led breeding networks and many small decisive experiments

Tony Gathungu
Climate Smart Technologies: A look through the product life cycle lens

Mark Edge
Partnership for Climate-Smart Maize in Africa: TELA Maize Project
Thank You!
Applied solutions to safeguard future wheat

Balancing production, resilience & sustainability

Alison Bentley, CIMMYT Global Wheat Program
Key take-aways

• Wheat is pivotal to **alleviation of hunger**, eaten by 2.5 billion people.

• >50% of the world’s wheat is grown in the Global South where projected yield declines due to climate change will **disproportionally impact production**.

• **Building resilience**, whilst maintaining productivity is crucial to safeguarding future production, underpinning food security.

• Wheat research & breeding are **accelerating improvement** and should be **integrated with system components** to achieve impact a scale.

• We require approaches to **rapidly and equitably accumulate and deploy** science innovations to smallholder farmers in the Global South.
Alleviating hunger

Maps produced by Kai Sonder (CIMMYT)
Alleviating hunger

Unequal impacts

• Patterns of global wheat production potential will change:
  – A large proportion of predicted yield decrease will occur in the Global South.
  – Projections highlight regions where climate impacts on wheat production are forecast to be greatest, allowing targeting of short, medium and long-term actions.
Building resilience

From: Xiong et al. (2021) Nature Plants
https://doi.org/10.1038/s41477-021-00988-w
Accelerating improvement

Accelerated population improvement & trait introgression

Pre-breeding and trait discovery for climate adaptation traits
Integrated systems

- Heat mitigation through management
  - E.g. providing buffering yield across temperatures.
Integrated systems
Optimizing varieties, cropping systems and on-farm mechanization.

Happy Seeder rice residue management system.
A combine is fitted with a Super Straw Management System (SMS) so that rice residue is spread evenly across the field during harvest. A Happy Seeder follows, planting wheat seed directly into the rice crop residue, and applying fertilizer.

1. Crop residue picked up and shredded
2. Seeds planted and fertilized
3. Shredded residue (mulch) dispersed
   a) Retains moisture
   b) Returns nutrients to soil

Combine harvests crop
Super SMS

seed & fertilizer
Equitably accumulating & deploying innovations

From: Gardeazabal et al. (2021) [https://doi.org/10.1080/14778238.2021.1884010]
Thank You

Find out more about the CIMMYT Global Wheat Program, our donors & partners:
https://www.cimmyt.org/work/wheat-research/
Breeding for Climate Change

Perspectives

Charlie Messina, PhD | Professor Horticultural Sciences University of Florida

FEED THE FUTURE: KNOWLEDGE, DATA, LEARNING, AND TRAINING (KDLT)

AGRILINKS
Breeding technologies demonstrated for adapting crops to stress conditions

The integrated use of precision phenotyping, managed stress environments, crop models, genomic prediction, and wide area on farm evaluations led to the successful development of AQUAmax\textsuperscript{(R)} drought tolerant maize. This approach was replicated over time and geographies building a foundation for adaption of crops to Climate Change.

Top Take-Aways

1. Framework for Breeding for Climate Change is lacking
   Scientists are generating partial views from environment challenges, operations & logistics, adaptive traits, and other views but a comprehensive framework is lacking.

2. Many journeys will be required to adapt to Climate Change
   Adaptation is a journey and each geography and community will define its own. During this journey we need to create and deliver products, not too fast and not too slow. Depending on GxE, breeding for 2100 climates may be detrimental to achieve 2025+ goals.

3. Breeding technologies demonstrated for adapting crops to stress conditions
   The integrated use of precision phenotyping, managed stress environments, crop models, genomic prediction, and wide area on farm evaluations led to the successful development of AQUAmax\textsuperscript{(R)} drought tolerant maize. This approach was replicated over time and geographies building a foundation for adaption of crops to Climate Change.

4. Success
   We can succeed by creating and agreeing on a framework, building on successful breeding technologies and approaches, and changing consuming behaviors.
**Approaches to breeding for climate change**

**Environmental Challenge**
Drought underpin yield losses under climate change scenarios.

**Crop and management design**
Heat stress tolerance, planting date, N fertilization.

**Quantitative Genetics (GxE)**
Recent research to bring awareness of GxE related to Climate Change.

**Breeding operations**
Selections today may not be suitable for future climates.

Increased ranking change in wheat breeding under climate change

Current warming will reduce yields unless maize breeding and seed systems adapt immediately

Wei Xiong, Matthew P. Reynolds, Jose Crossa, Urs Schuitteh, Kai Sonder

Genotype x environment interactions complicate selection
Framework core objectives

STOP
Externalities
GHG emissions

Regenerate
Aquifers
Soils
Agroecosystems

Deliver
More productive, nutritious & stable crops
For today and the future
Circularity in Agriculture

See MacArthur Foundation

Need a systems view
A patch in agriculture is not a feasible solution

GH3 emissions

Externalities

Increased biotic and abiotic stress

Climate Change

Agriculture

Human Health

Productivity
Human Health, Climate Change and Agriculture connected through Diets

Agriculture produces what humans demand
Changes in Ag will start with change in Diets
Changes in Diets will redefine breeding objectives

Climate Change
- GHG emissions
- Externalities
- Increased biotic and abiotic stress

Agriculture
- Demand
- Plant Breeding
- Supply
- Behaviour
- Diets Specs
- Productivity

Diets

Human Health
- NRD
What is the role of breeding as a driver of change?

- Translate societal demands into genetic solutions to enable the transformation of agriculture for improved adaptation to climate (& social) change.
Transition to circular agriculture... Build upon a proven method

Precision Phenotyping

Managed Stress Environments

Large scale On Farm evaluations

Crop Model-Whole genome prediction
Theory meets evidence

Drought Tolerance

Yield gap (g m⁻²)

Control Checks Gen 1 2011 Gen 2 2018

Drought tolerant maize

Evapotranspiration (mm)

Grain yield (Mg ha⁻¹)

Yield gap
Multidimensional framework

1. Empower decision makers to approach dilemmas
2. Require new prediction methodologies
3. Deal with long-term systems changes (eg, carbon, aquifers)
Prediction in multiple dimensions

More yield and carbon sequestration at the expense of higher water use... balance C sequestration, externalities and food production

TOP TAKE-AWAYS

1. Framework for Breeding for Climate Change is lacking

2. Many journeys will be required to adapt to Climate Change

3. Success: Build upon successful breeding technologies
How to adapt sorghum for climate change?
NARS-led breeding networks and many small decisive experiments

Geoff Morris
Associate Professor, Crop Quantitative Genomics, Colorado State University
Key points:

1. NARS-led breeding networks are essential
2. Complex traits require simple approaches
What roles for NARS, CG, and IL would best serve smallholders?
Our stakeholders are diverse. Knowledge on their needs and wants (demand) is highly localized and diffused.
Our stakeholders are diverse. Knowledge on their demand is highly localized and diffused.
NARS are in the best position to

(1) understand and aggregate knowledge on local demand and

(2) develop and deliver varieties based on this knowledge
NARS are in the best position to
(1) understand and aggregate knowledge on local demand and
(2) develop and deliver varieties based on this knowledge
CG is in the best position to provide foundational R&D support at scale, across crops and geographies.
CG is in the best position to provide foundational R&D support at scale, across crops and geographies.

Specialized research expertise

Training
Genotyping
Informatics
Genebank
Introgression
Pre-breeding
etc.

NARS
Diverse local stakeholders

OneCG

Diverse local stakeholders

Diverse local stakeholders

Diverse local stakeholders

Diverse local stakeholders

Diverse local stakeholders

Local knowledge on varietal demand
ILs are in the best position to provide *specialized* research expertise and *targeted* project funding
ILs are in the best position to provide **specialized** research expertise and **targeted** project funding.
Key points:

1. NARS-led breeding networks are essential

2. Complex traits require simple approaches
History of NARS breeding:
Forward pedigree breeding in small populations

Preferred variety
- Adapted flowering time
- *Striga susceptibility*
- Sufficient forage
- Preferred grain quality

Donor variety
- Maladapted flowering time
- *Striga resistance*
- Insufficient forage
- Unacceptable grain quality
History of NARS breeding:
Forward pedigree breeding in small populations

- **Preferred variety**
  - Adapted flowering time
  - *Striga susceptibility*
  - Sufficient forage
  - Preferred grain quality

- **New variety**
  - Adapted flowering time
  - *Striga resistance*
  - Sufficient forage
  - Unacceptable grain quality

- **Donor variety**
  - Maladapted flowering time
  - *Striga resistance*
  - Insufficient forage
  - Unacceptable grain quality

Limited adoption

Sorghum and millet adoption: Walker & Alwang 2015
Does NARS breeding for complex traits (e.g. climate adaptation) need complex approaches?

Lozano et al. Nature Plants 2021

Genome sequencing

Climate modeling

Jägermeyr et al. Nature Foods 2021

Genomic selection

Plant Phenomics

terraref.org
Complex traits require simple approaches

- Why did leading seed companies develop and adopt these complex approaches? (genomics, phenomics, modeling)

- Technology that facilitates many small decisive experiments
  - Genomic prediction, managed stress trials, or in silico experiments

- Wrong lesson: Transfer technology that leading seed companies used

- Right lesson: Use the disciplined problem-solving approach they applied
What technologies could facilitate many small decisive experiments for NARS?

• **Scientific method**
  – Focus on excluding hypotheses as quickly as possible (Platt 1964 *Science*)

• **Breeding fundamentals**
  – Product profiles, seed purity, phenotyping accuracy, etc.

• **Classical genetics**
  – Track major genes, simple markers, test hypotheses using phenotype, etc.

• **Use or adapt whatever new technology is necessary**
  – But only when necessary, and only with hypothesis testing
Example: Leveraging introgression lines

- In conclusion: How to adapt for climate change from now–2050?
  Help NARS breeders develop varieties that will be adopted in 2025

(Synthesizing ideas of Jordan et al. 2011 *Crop Science* and Haussmann et al. 2012 *JACS*)
Thank You
NARS breeder/researcher collaborators:
Cyril Diatta, Nofou Ouedraogo, Eyanawa Akata, Ardaly Ouesseini, Aissata Mamadou, Ndiaga Cisse, Daniel Fonceka, Jacques Faye, Fanna Maina, Kebede Muleta, Gael Pressoir

USAID Feed the Future and Bill & Melinda Gates Foundation:
Sorghum Millet Innovation Lab (SMIL) & Innovation Lab for Crop Improvement (ILCI)
Sorghum Genomics Toolkit (SGT) & Mining Useful Alleles for Climate Change Adaptation

Geoff.Morris@colostate.edu
www.CropAdaptation.org
Scaling of Climate-Smart technologies

A look through the Product Life Cycle Lens
What we do

A brighter future for smallholder farming

- AGRISERVICES
- INSURANCE
- SEEDS2B

RESEARCH & DEVELOPMENT

POLICY
Elements of our work on Climate Change

• Climate-smart, resilient agriculture (CSRA) is a core component of SFSA’s renewed strategic framework, strengthening our ambition to support smallholder farmers to better deal with the consequences of climate change

• SFSA works on a variety of initiatives that support climate-smart farming systems across all its streams

• Delivering and scaling of climate-smart technologies is at the core of our Seeds2B model of variety commercialization

• Catalyzing strategic partnerships along the value chain is key to bring climate-smart technologies to smallholder farmers
PLC End to end process of variety commercialization

Problem Definition

Solution Design

Solution Delivery

R&D - BREEDING

COMMERCIAL

OWNERSHIP

PLC STAGE

% Sales

1 – 2

3

4

5

6

7

8

9

10

11

12

Concept & Breeding

Prototype

Early development

Late development

Testing & Registration

Introduction

Growth

Maturity

Decline

Phase out

Out of assortment

Solution Delivery

% Sales
### A deeper dive into the process

#### Problem Definition

<table>
<thead>
<tr>
<th>Identify farmer needs</th>
<th>Solution Design</th>
<th>Solution Delivery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crop &amp; country scoping</td>
<td>Design value proposition</td>
<td>Draft business models including partnerships</td>
</tr>
<tr>
<td>Farmer challenges assessment</td>
<td>Targeted farmer segment</td>
<td>Business model, stakeholder mapping, licensing models</td>
</tr>
<tr>
<td>Value Chain Analysis</td>
<td>Market segmentation/TPP</td>
<td>Financial analysis for SHF (Farmer ROI), environment and social benefits (solution)</td>
</tr>
<tr>
<td>SWOT Context</td>
<td>Solution statement (hypothesis)</td>
<td>Economic value analysis for SHF (Farmer ROI), environment and social benefits (solution)</td>
</tr>
</tbody>
</table>

**Draft business models including partnerships**

- Investment case: Benefits/cost (NPV and sensitivity analysis)

**Solution Design**

- **Write Launch road map and launch timelines**
- **Create marketing mix: portfolio, price, promotion, place, packaging**

**Solution Delivery**

- **Launch road map**
- **Launch timeline, including registration**
- **Portfolio Life cycle**
- **Trial creation and execution**
- **Variety performance**
- **Actual variety profile against TPP**
- **Value pricing**
- **Promotional guidelines (branding, packaging, demand creation)**
- **Distribution pathway**
- **Seed production**
- **Seed production manual (EGS + commercial)**
- **Where, how, production recipe**
- **Legal framework**
- **Legal framework to operate (registration, sales licenses, MTA, MITTA, commercial and licensing agreement)**
- **Planning process**
- **Product Advancement Meeting (PAM)**
- **Sales forecast**
- **Seed Production plan (SPP)**
Case Example – AAA Maize in India

PROBLEM DEFINITION
Increasing access for smallholders in semi-arid West Central India to high-yielding, climate smart resilient and affordable maize varieties

SOLUTION DESIGN
AAA hybrid maize – drought tolerant, yielding 2X of OPVs and 80% of popular hybrids and local checks

Market & Product segmentation
Economic Benefits
Environmental Benefits
Social Benefits
Business Models
Investment Case

SOLUTION DELIVERY
AAA hybrid maize delivered by local SMEs, NGOs and Agri-entrepreneurs: 12,000 farmers grew AAA maize in 2021 Kharif season
## PROBLEM DEFINITION

Support crop diversification in Samburu, a primarily pastoral and semi-arid area of northern Kenya with recurring drought.

## SOLUTION DESIGN

- Partnership with The International Potato Center, KALRO, and SFSA to trial adapted potato varieties

## SOLUTION DELIVERY

- >2,500 farmers adopted potato production in year 1
- 15 MT tons of EGS produced in Samburu county

<table>
<thead>
<tr>
<th>Attribute</th>
<th>CIP</th>
<th>KALRO</th>
<th>SFSA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altitude</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drought Tolerance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disease resistance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maturity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nematode Resistance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dormancy</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Demonstration of heat-tolerant and early maturing varieties *Wanjiku* and *Unica*.

Diversification of economic activities by the introduction of alternative food sources.

Expansion of potato growing zones to increase the total production in the country. High productivity with disease-free soils.

Demonstration of highly nutritious potato varieties. *Unica* is rich in Vitamin C, Iron, and Zinc.
Parting Thoughts

• Climate change is one of the most important issues the world must tackle today

• Helping farmers to be able to adapt to these changes and be part of the solution to climate change is at the core of what we **MUST** do
Thank You

www.syngentafoundation.org
Partnership for Climate-Smart Maize in Africa

TELA Maize Project

Mark Edge, Bayer Crop Science

February 10, 2022
Impact at scale for climate adaptation with climate-smart maize in Africa hinges on three things:

1. Partnerships
2. Products that deliver value and reduce risk for farmers
3. Sustainable holistic seed systems for delivery to the farmer

The TELA® Maize Project as a case study
TELAR® Maize Project

Developing *Climate-smart* TELAR® Maize Hybrids for African Farmers

Vision & Mission

To increase yield stability and reduce risk under drought conditions through breeding and biotech

**GERmplasm**
- Disease Tolerance
- Drought Tolerance
- Yield Potential

**AGRONOMIC PRACTICES**
- Farm-level Recommendations

**TRAIT PACKAGES**
- Insect Control
- Drought Tolerance
**Public-Private Partnership**

**TELA® Maize**

**Framing the partnership – initiated in 2008**

---

**Partners**

- **World Leader for breeding maize**
  - for African agro-ecological zones (East and Southern Africa)

- **AATF**
  - Capacity to access, develop, & deliver *appropriate agricultural technologies* to smallholder African farmers

- **World Leader in GM crops**
  - **Donated royalty-free:**
    - Proprietary germplasm
    - Drought-tolerance trait
    - Insect-protection (Bt) traits
    - Regulatory data packages

---

**Roles**

- **World Leader for breeding maize**
  - Capacity to access, develop, & deliver *appropriate agricultural technologies* to smallholder African farmers

- **NARS**
  - Expertise in field trials
  - Breed/Test & release new hybrids
  - Regulatory approvals

---

**Funded by**

- **USAID**

---

**Countries in scope**

*NARS = National Agricultural Research System*
TELA® Maize Product Concept

Objectives

• White Hybrids (Single-cross or 3-way)
• 25% yield improvement compared to 2008 hybrids under moderate drought conditions
  – Target 15% from breeding over 10 years
  – Additional 8–10% from DT transgene
  – Insect protection from Bt transgene

• General Product Requirements
  – Drought tolerance
  – Maturity 125–135 days
  – Disease resistance: GLS, TLB, MSV and MLN
  – Agronomic traits: root-lodging, prolificacy, maturity, husk cover

• Consumer Requirements
  – Maintain required milling quality
  – Maintain meal yield
  – Grain Texture: flint to flinty-dent
Success Story

**DroughtTEGO®**

Hybrids Mean Yield Across Locations and Seasons; Kenya


TEGO hybrids are conventional (non-GM) with improved drought tolerance

Primary Goal and Key Components

Primary Goal:
Secure Approvals and Initiate Products Commercialization
In at least 4 African countries by 2023

GM Status in Africa:
• No commercial GM maize approved for sale yet in Sub-Sahara Africa (ex RSA)
• Bt Cotton (Kenya, Malawi & Nigeria) and Bt Cowpea (Nigeria) are in the market
• Nigeria approved Bt Maize but it will require 1 season for variety registration
• TELA Maize project is leading the way for GM maize approvals in SSA

Approval and Commercialization Process:
1. Development, submission of dossier and management of review process
2. Advocacy, outreach and communications
3. Testing and approval of compelling products
4. Commercialization and deployment
Confined Field Trials (CFT) Data META Analyses

Efficacy of GM* vs Non-GM Hybrids
(2016–2020; 6 Locations – 12 CFTs: KE, UG, TZ, MZ, and ET)

On average, 43% yield advantage of stacked GM hybrids with Bt MON810 relative to Non-GM iso-hybrids.

*GM = Genetically Modified
**Why TELA Works**

- Builds on Core Strengths
- Common Objectives
- Focused on specific outcomes
- Long-term commitments by partners & donors

**Challenges Remaining**

- BIOTECH APPROVALS
- SEED COMPANY SCALING
- QUALITY SEED PRODUCTION
- FARMER AWARENESS
- STEWARDSHIP
- GEOGRAPHICAL EXPANSION
Thank You!

Mark Edge
Director of Partnerships, Seeds & Traits Development for LMICs
Email: mark.edge@bayer.com
Thank you!